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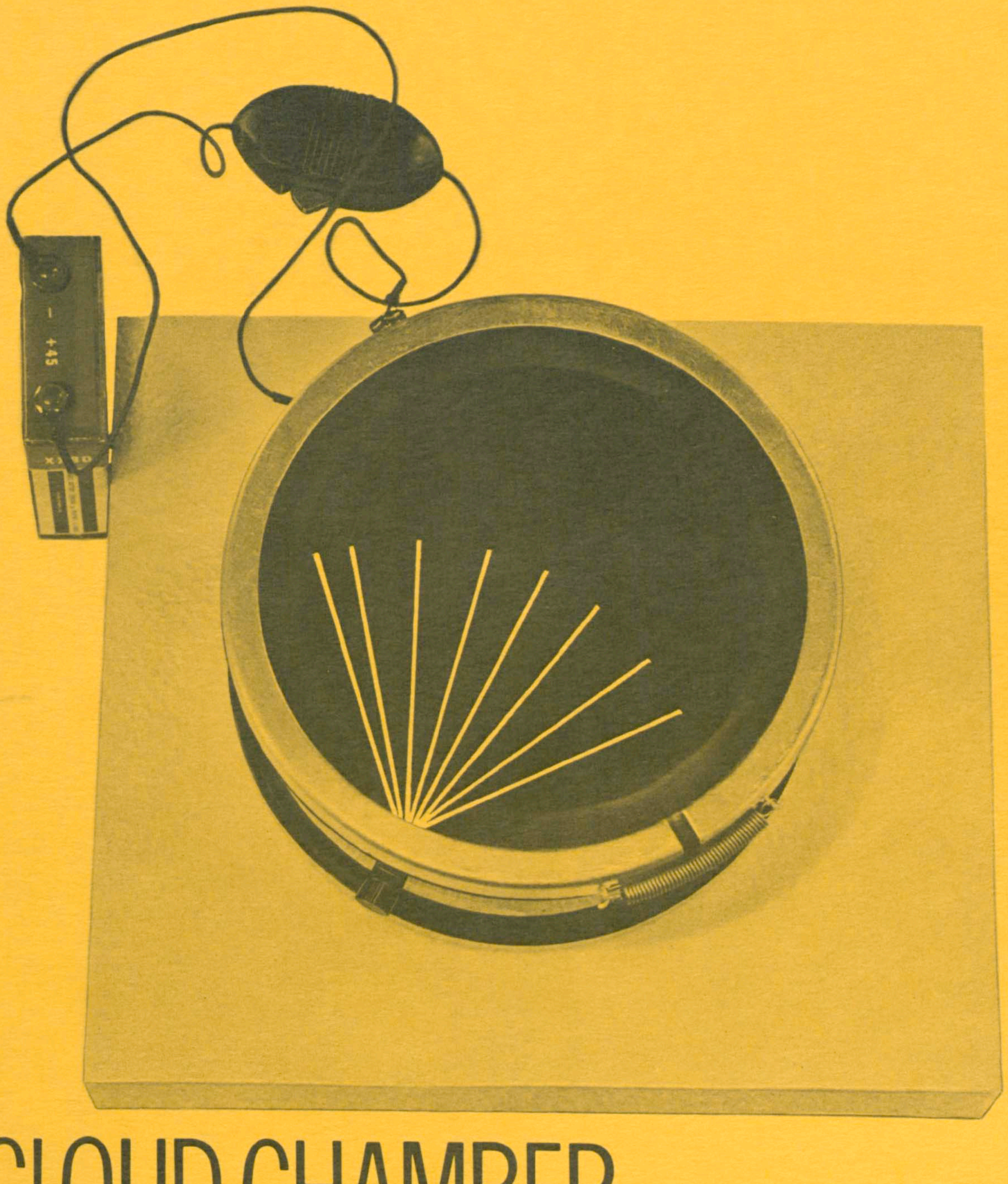

THE CLOUD CHAMBER

Supersaturated Vapors and Radioactivity.

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A Module on Supersaturated Vapors and Radioactivity

ORAU

Homer C. Wilkins, Project Director

Homer C. Wilkins, Oak Ridge Associated Universities

MCGRAW-HILL BOOK COMPANY

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Philip DiLavore .... Editor
Julius Sigler .... Rewrite Editor
Mary Lu McFall .... Copy and Layout Editor
B. W. Barricklow .... Illustrator
Stacy Garrett .... Compositor
Elsie Green .... Compositor
Lauren Eli .... Compositor
Donald Emmons .... Technical Proofreader

In the early days of the Tech Physics Project A. A. Strassenburg, then Director of the AIP Office of Education, coordinated the module quality-control and advisory functions of the National Steering Committee. In 1972 Philip DiLavore became Project Coordinator and also assumed the responsibilities of editing and producing the final page copy for the modules.

This module was written and tested at the Oak Ridge Associated Universities, and with funding of the Atomic Energy Commission.

The authors wish to express their appreciation for the help of many people in bringing this module to final form. The criticisms of various reviewers and the cooperation of field-test teachers have been most helpful. Several members of the staff of Oak Ridge Associated Universities also deserve special recognition for their contributions. They are: Lawrence K. Akers, John F. Yegge, John Amend, Jerry Minter, Bernie Korn, Becky Stodghill, and Jo Templeton.

The Cloud Chamber

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THE CLOUD CHAMBER

PREFACE

In this module you will assemble a device called a *diffusion cloud chamber* and use it to study radiation from radioactive materials, such as radium. The discussion of how it works will lead to an understanding of such things as fog formation, cloud seeding, supersaturation, and the cooling effect of perspiration.

The module is written so that you can proceed through it with a minimum of help from your instructor. The instructions for the experiments and other work are easy to identify in the text, even though they are mixed in with the discussion.

Some of the questions are designed to stimulate further thought and cannot usually be answered by quoting the text material. You should be able to answer each question, however, by a combination of an understanding of the text material, some common sense, and perhaps some previous knowledge of science. The questions can be the basis of discussions with other students, in or out of class. In some cases your teacher may ask you to write out answers to the questions and hand them in. The ability to formulate clear, concise answers to such questions is an important and desirable goal.

The author wishes to express his appreciation of the help of many people in bringing the module to its final form. The clerical and other support staff of Oak Ridge Associated Universities deserve special recognition. Field-test teachers and their students have been very helpful. Their criticisms of early editions have been greatly appreciated, even if often-times painful. The same thing can be said about other reviewers.

For the author, the production of this module has been a learning experience, through study, discussions, and the criticisms of reviewers and students. It has also been an enjoyable experience. We hope that your use of the module will also be a gratifying, learning experience.

GOALS

As you work through this module you will learn:

1. How to detect moving charged particles.

2. How to identify the charged particles which you detect.

3. The effect of particle mass and charge on the formation of tracks in the cloud chamber.

4. How to describe the processes of evaporation and condensation.

5. The effect of cooling a vapor to a temperature lower than its normal condensation temperature.

6. The effect of cooling a liquid to a temperature lower than its normal freezing temperature.

7. The relationship between vapor condensation and a variety of naturally occuring phenomena, such as the formation of frost, dew, and fog.

8. How to measure the rate at which charged particles are given off by a radioactive material.

SECTION A

How a Diffusion Cloud Chamber Works

INTRODUCTION

This module is concerned with an important device for observing the paths of charged particles in a gas. Particles of atomic and sub-atomic sizes cannot be seen directly, even with the best microscopes. But with a *diffusion cloud chamber,* the paths of nuclear particles can be made visible. It is like the hunter who may not see the fox but can see where it has *been* by following its tracks in the snow. An experienced hunter may learn a great deal about the fox (weight, size, age, physical condition, etc.) simply by examining the trail the fox leaves.

It is now generally agreed that all ordinary materials are composed of atoms. Each atom consists of a *nucleus* surrounded by a number of *electrons.* Each electron has a small amount of *negative* electric charge which is the same for every electron.* The nucleus has an amount of *positive* electric charge which is exactly equal to the charge of all the surrounding electrons combined when the atom is electrically neutral. If an electron is somehow removed from (or added to) the atom, then the net charge of what is left is no longer zero. We call such a charged atom an *ion* (from a Greek word meaning *carrier*—a carrier of charge), and we say that the atom has been *ionized.* When an electron is removed from a neutral atom, the positive ion and the electron which was removed from the atom are together called an *ion pair.* When an atom is stripped of all its electrons, thus leaving only the nucleus, it is sometimes given a special name; for example, a *proton* is the nucleus of a hydrogen atom and an *alpha particle* is the nucleus of a helium atom.

Some materials (e.g., radium) are said to be *radioactive.* This means that they give off particular kinds of radiation, historically labeled by using the first three letters of the Greek alphabet (α, β, γ). Alpha (α) and beta (β) radiation are known to be rapidly moving particles. The alpha particle has the same mass and charge as the nucleus of a helium atom. Some beta particles are negatively charged and are identical to ordinary electrons. Positive beta particles are called positrons. They have the same mass as electrons. Gamma (γ) radiation has no mass or charge but has many of the properties of light. Usually a particular radioactive material gives off only one kind of radiation.

When a charged particle (such as an alpha or a beta particle) passes through a gas, it leaves behind it a trail of ion pairs; and it is these ions that make it possible for us to see the paths of the charged particles. The paths of these particles (called *tracks*) are made visible in a cloud chamber. This module will describe the construction and operating principles of such a cloud chamber. The sources used with the cloud chamber are made of radioactive materials. (**Caution**: The intensity of radiation is very low and no danger is involved if the materials are used properly. However, you should be careful not to touch the sources against your skin, or anything else other than the container in which they are stored.)

*The charge on an electron is approximately -1.6×10^{-19} coulombs.

EXPERIMENT A-1. Operating a Cloud Chamber: Radium Tracks

Before going further into the theory of the device, you should construct a cloud chamber and do some experiments with it. You have been provided with the materials for doing this.

The main part of this cloud chamber is a cylindrical plastic box. (See Figure 1.)

You will see that the bottom of the chamber has been darkened to make the tracks more visible. Holes in the side and cover permit inserting objects for study.

To prepare the chamber for operation cut and staple a strip of blotting paper so that it fits snugly inside the chamber near the top, as shown in Figure 1. Moisten the strip of blotting paper with alcohol and slip it into place in the chamber. Place the chamber on a slab of dry ice. (**Caution**: Since dry ice is *very cold*, care must be exercised in handling it. Use heavy gloves, preferably ones made of asbestos.)

Identify the radium source and insert it down through the center hole at the top of the cloud chamber. Adjust it until the source at the tip of the probe is close to but not touching the bottom. All the other holes should be plugged with corks and the lid should fit tightly, since air currents through any opening will prevent operation of the chamber.

Within a few minutes after the chamber has been placed on the dry ice, tracks of the charged particles should start appearing. In a semi-dark room, illuminate the chamber from the side with a flashlight. The tracks should be visible against the dark bottom. (See Figure 2.)

Now *slowly* raise the source in the chamber and record your findings. You might try this soon after tracks begin to appear and then some time later. Is there any difference?

Several questions may have occurred to you: Why did the tracks not appear immediately? Why are no tracks visible near the top of the chamber? Why are the tracks visible at all? In order to be able to answer such questions and to understand other experiments you can do with the cloud chamber, you will need to understand some of the processes involved, especially those having to do with the condensation of vapors.

Before you leave the cloud chamber to do some further reading, find the temperature at several vertical positions in the chamber. Take a reading near the bottom, halfway up, and near the top. How do the three values compare?

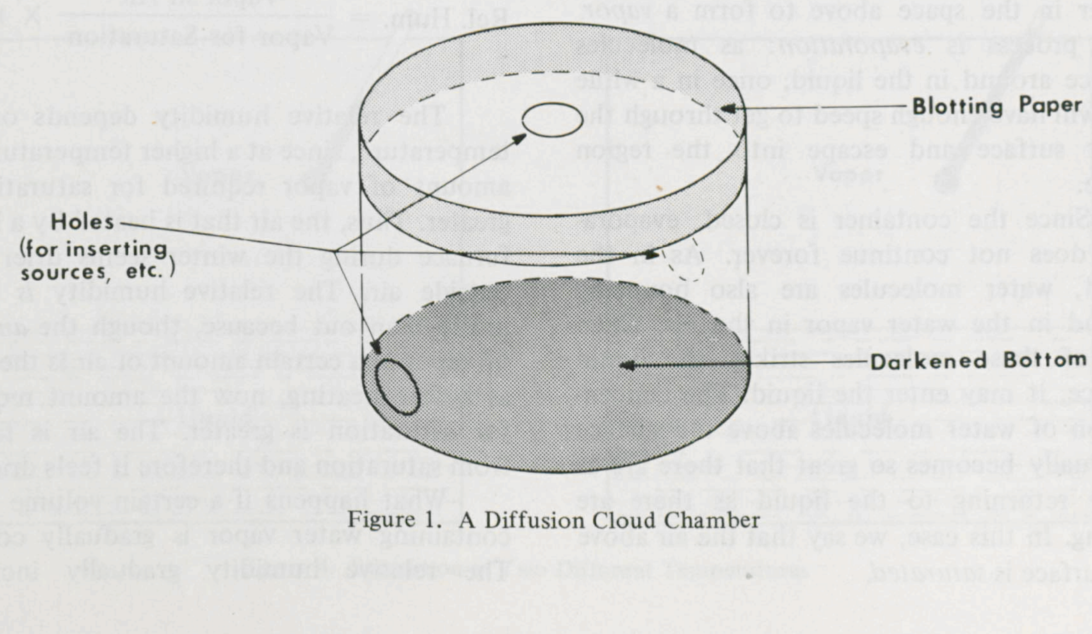


Figure 1. A Diffusion Cloud Chamber

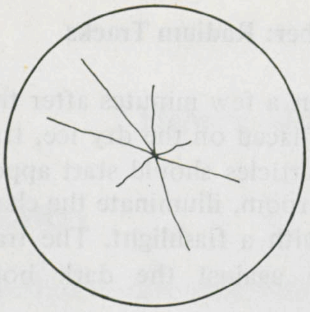


Figure 2. Tracks from a Radium Source

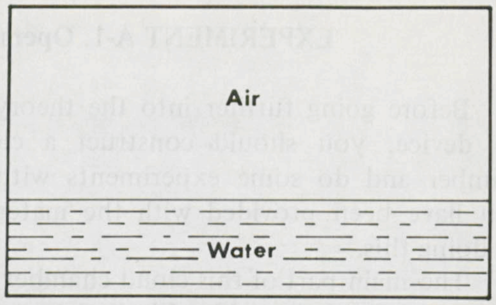


Figure 3. Air and Water in a Closed Container

Question 1.

Why is the bottom of the cloud chamber darkened?

VAPORS AND SATURATION

The cloud chamber operates because the air inside it contains alcohol vapor. Several important properties of vapors can be illustrated by using water as an example. For example, everyone has observed the evaporation of water; let us look more closely at this process.

Consider a closed container of air and water, as shown in Figure 3. Suppose that we could start with dry air above the water (the air would then contain no water molecules) and that the air and the water start at the same temperature. We could find that water molecules gradually leave the liquid and gather in the space above to form a *vapor.* This process is *evaporation*: as molecules bounce around in the liquid, once in a while one will have enough speed to get through the water surface and escape into the region above.

Since the container is closed, evaporation does not continue forever. As in the liquid, water molecules are also bouncing around in the water vapor in the air. When one of these molecules strikes the liquid surface, it may enter the liquid. The concentration of water molecules above the surface eventually becomes so great that there are as many returning to the liquid as there are leaving. In this case, we say that the air above the surface is *saturated.*

If the above procedure is repeated at a higher temperature, saturation will again take place, but with some differences. For example, the rate of evaporation at the start is greater than at the lower temperature, and the final concentration of water molecules above the surface is also greater. (See Figure 4.) This is the case because, at the higher temperature, the average speed of the molecules is greater and more of them are thus able to escape through the surface of the water.

(We are using the word *vapor* to mean a gaseous material which is near the saturation point. This is a more restricted meaning of the word than that used commonly.)

To refer to water vapor in the atmosphere, the word *humidity* is used. *Relative humidity* is the per cent of saturation. It is the actual amount of water vapor in the air divided by the amount required for saturation at that temperature, and multiplied by 100%:

$$\text{Rel. Hum.} = \frac{\text{Vapor in Air}}{\text{Vapor for Saturation}} \times 100\%$$

The relative humidity depends on the temperature, since at a higher temperature the amount of vapor required for saturation is greater. Thus, the air that is heated by a house furnace during the winter seems drier than outside air. The relative humidity *is* lower inside than out because, though the *amount* of vapor in a certain amount of air is the same as before heating, now the amount required for saturation is greater. The air is farther from saturation and therefore it feels drier.

What happens if a certain volume of air containing water vapor is gradually cooled? The relative humidity gradually increases

(because the amount for saturation decreases) until the air is saturated. If the temperature goes even lower, some of the vapor goes back into the liquid state. That is, *condensation* takes place. (See Figure 5.)

The temperature at which the air becomes saturated is called the *dew point*.

Condensation can take place in various forms. If it takes place throughout a large volume of space, then fog or a cloud appears. If the vapor near a surface is especially cooled, then condensation can take place *on* the surface, in the form of dew. If the surface is below the freezing point, then the water passes directly from the vapor form to the solid form and the result is frost.

EXPERIMENT A-2. Dew Formation

At this point, you might want to try an experiment. Partially fill a flask with hot water and tightly stopper it. Now gradually cool the flask. You should observe dew forming on the inside surface.

You have probably also observed that a car windshield often "fogs up" on a cool day, especially if several people are in the car.

Another experiment you may have already tried is to blow your breath on a window pane or other cool surface. Condensation often takes place.

Condensation on a surface takes place when the air in contact with that surface is cooled below the saturation temperature. Often if there is a wind, the air does not stay near the cool surface long enough to reach saturation and no dew or frost forms.

You are familiar with the change from liquid to vapor brought about by heating. In ordinary evaporation no heat is supplied and the heat required for evaporation comes from the liquid. This means that the liquid becomes cooler. That is why you feel chilled when you come out of a swimming pool, even on a hot day. By the evaporation of moisture, your body is cooled. Your body temperature is regulated similarly. As you exercise, heat is lost by the evaporation of perspiration.

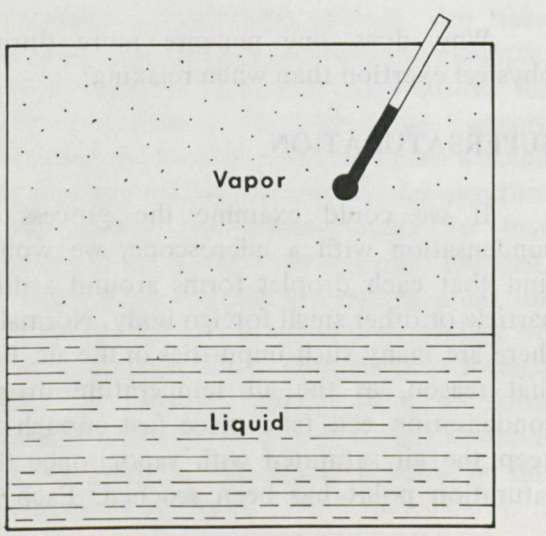
When vapor condenses, heat is given off. The same amount of heat is given off as is required for the evaporation of the same amount of water.

Question 2.

It is more likely that a car windshield will "fog up" with four people in the car than with only one. Why?

Question 3.

Why does fog form on a window pane when you blow on it?



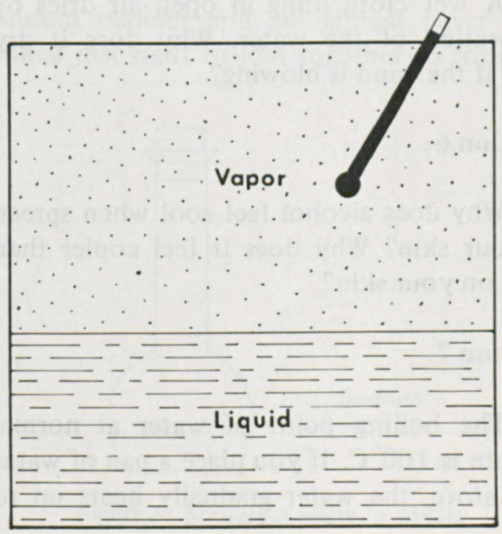


Figure 4. Saturation at Two Different Temperatures

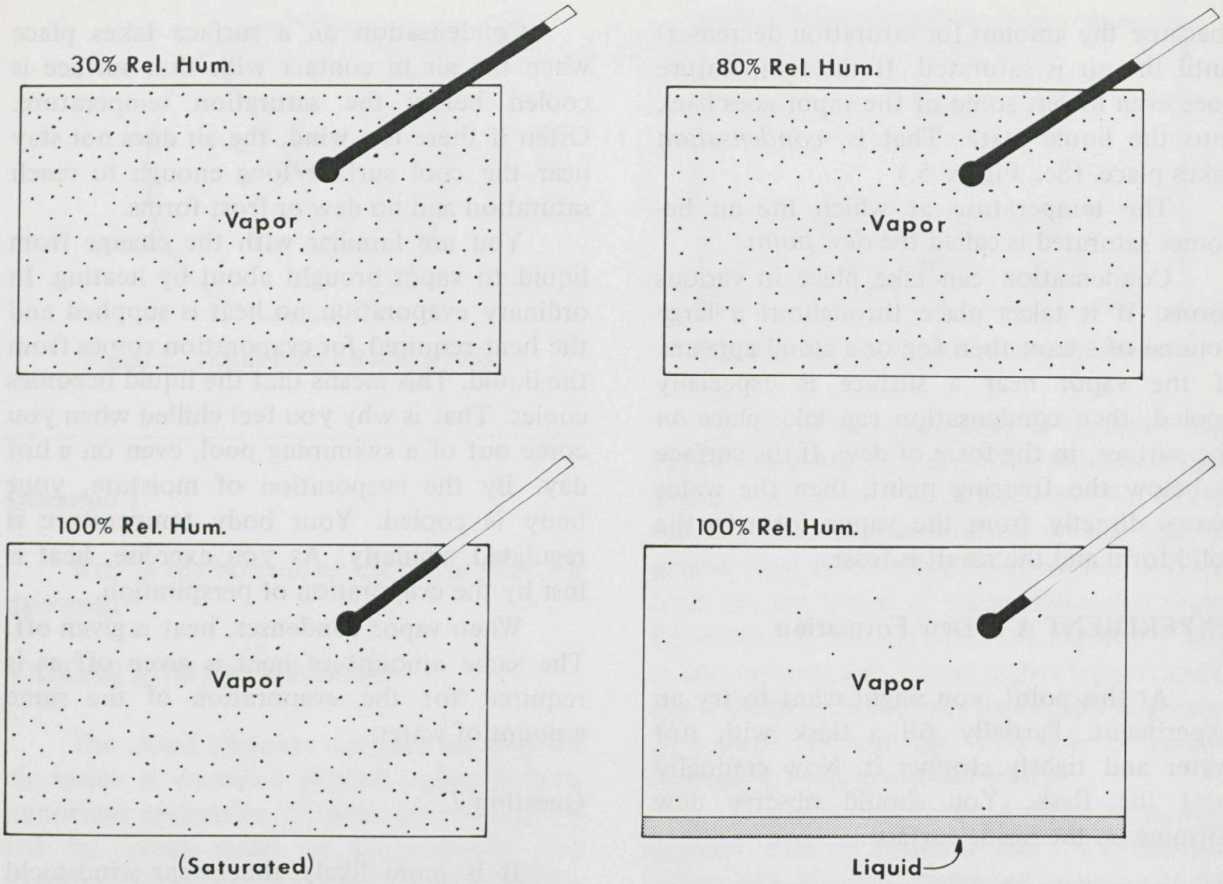


Figure 5. As Temperature Decreases, Humidity Increases and Condensation Takes Place

Question 4.

Is frost frozen dew?

Question 5.

A wet cloth hung in open air dries by evaporation of the water. Why does it dry faster if the wind is blowing?

Question 6.

Why does alcohol feel cool when spread on your skin? Why does it feel cooler than water on your skin?

Question 7.

The boiling point of water at normal pressure is 100°C. If you place a pan of water on a stove, the water gradually heats up to 100°C and remains at that temperature until it all boils away. Why is it that the water does not suddenly all boil away if it is all at the boiling point?

Question 8.

Why does one perspire more during physical exertion than when relaxing?

SUPERSATURATION

If we could examine the process of condensation with a microscope, we would find that each droplet forms around a dust particle or other small foreign body. Normally there are many such impurities in the air. For that reason, as the air temperature drops, condensation can take place fast enough to keep the air saturated with vapor, once the saturation point has been reached. Each of

these small foreign bodies is called a *condensation nucleus,* or simply a *nucleus.* In our cloud chamber studies the word *nucleus* has a different meaning (the atomic nucleus); the term *condensation sites* is used to designate the bodies on which condensation takes place.

In a clean vapor which has *no* condensation sites, condensation does not take place as the temperature reaches the saturation point. Even if the temperature goes lower, condensation does not take place because of the lack of condensation sites. The vapor is then said to be *supersaturated.* If such sites (foreign matter) are added, condensation can immediately take place. In some cases, even if there are many condensation sites available, supersaturation can take place if the temperature drop is abrupt.

To produce rain artificially *cloud seeding* is done by releasing into cold air many small particles that can act as condensation sites.

Question 9.

Explain the white vapor trail ("contrail") left by a jet plane at high altitude.

LIQUIDS: SUPERHEATED AND SUPERCOOLED

We have discussed supersaturating a vapor by cooling it below the saturation temperature. Interesting effects also take place for other changes of form. For example, a liquid boils at different temperatures for different pressures: the higher the pressure the higher the boiling point. Suppose a liquid is at a high pressure and that the temperature is just below the boiling point for that pressure. If the pressure is suddenly reduced, the liquid then is above the boiling point for the new pressure. If it is not then boiling we say that the liquid is *superheated.* If foreign bodies are present, bubbles of vapor form around the foreign bodies. If no such *bubble sites* are present, the liquid remains in the superheated condition.

In a similar way, when a liquid is cooled to the freezing point and below, solidification takes place around foreign bodies, if any are present. The liquid becomes *supercooled* if the temperature drop is sudden. It may remain a supercooled liquid if there are no sites around which the solid can form.

Some materials are very selective as to the kinds of particles that can be condensation sites. This can be seen in the following experiment.

EXPERIMENT A-3. Solidification of Sodium Acetate

Place into a 250-ml flask (or other container) 50 g of sodium acetate in solid or granular form. After adding a few drops of water, put the flask into a pan of boiling water. In a few minutes the sodium acetate will become a liquid, as indicated in Figure 6. Stopper the flask loosely and set it aside to cool. Note that the sodium acetate does not re-solidify as the temperature goes back to the original value. It is supercooled. You might try various ways to cause solidification (shake it gently, cool it more, etc.)

Remove the stopper and drop into the liquid a tiny granule of solid sodium acetate. What happens?

In this case the granule is in what is known as a *crystalline state.* That is, the atoms are arranged in a particular manner. In the liquid the molecules are colliding in a random manner and are almost never positioned just right to join together to form the

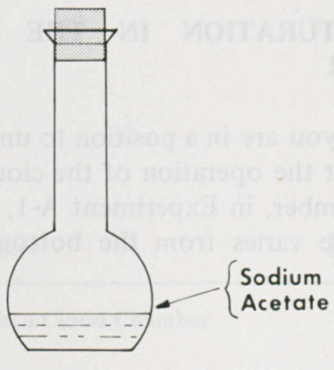


Figure 6. Sodium Acetate in a Flask

solid. A sliver of crystal of the material already has its atoms arranged properly and molecules hitting the crystal have a much higher chance of becoming attached, and therefore increasing the amount of solid.

Notice that, as the liquid solidifies, the container becomes quite hot. Recalling that heat was required to liquify the solid, can you guess why the container feels hot?

This example with sodium acetate shows the important features of most changes of form. In the case of condensation of vapor these properties are not so visible, but they are similar to those for the solidification of sodium acetate. In both cases supercooling occurs if no condensation sites are present. Condensation usually takes place quickly if condensation sites are provided. Heat is given off as condensation takes place.

Question 10.

A jar of distilled water in the trunk of a car had not frozen when the outside temperature was 0°F. Almost immediately after the lid was removed, the water froze solidly. Can you explain this?

Question 11.

When water in a pan begins to boil (or when a bottle of carbonated drink is opened), bubbles of gas often form at a blemish on the bottom. Can you explain this?

SUPERSATURATION IN THE CLOUD CHAMBER

Now you are in a position to understand more about the operation of the cloud chamber. Remember, in Experiment A-1, how the temperature varies from the bottom to the top of the chamber. The dry ice underneath lowers the temperature near the bottom of the chamber to a temperature *below* the saturation point; that is, the vapor is supercooled. It is ready to condense, as soon as condensation sites become available. Those condensation sites are provided by the charged particles which are given off by a radioactive source. As those particles go tearing through the vapor, they knock electrons off some of the molecules and produce positively-charged ions. These ions can act as condensation sites for forming droplets of alcohol. Since the ions are produced along the path of a radioactive particle, the tiny clouds formed are "tracks" which show where the radioactive particles have been recently.

You might be interested in knowing that the earliest cloud chambers produced supersaturation by expansion. When air expands, it is cooled (also when it is compressed, the temperature rises). If the air is already saturated, then expansion causes supersaturation. Obviously, particle tracks can be seen only for the short duration of supersaturation; that is, until the vapor warms up again.

SUMMARY

In this section you learned to operate a diffusion cloud chamber to observe tracks of charged particles. Then you studied the various processes that take place in its operation. In this study you learned about such topics as saturation of vapors, condensation, and supercooling.

In an experiment using sodium acetate you were able to see a dramatic case of supercooling of a liquid. The rapid solidification was triggered by the addition of a small sliver of solid sodium acetate.

You learned how the principles of operation of the cloud chamber help us understand such topics as humidity, cloud seeding, and the formation of fog, dew, and frost.

SECTION B

Further Experiments with the Cloud Chamber

EXPERIMENT B-1. A Closer Look at Cloud Chamber Tracks

Now that you have assembled a cloud chamber and considered the principles of its operation, you might want to observe the tracks more carefully and do some additional experiments. Arrange the cloud chamber for operation just as in the previous section.

Notice that the tracks are distinct lines—they are produced by rapidly moving particles. But they occur at unpredictable times and in unpredictable directions.

Most of the particles giving rise to the tracks are *alpha particles.* (Remember, an alpha particle is a helium nucleus, and it has a positive charge.) It is known that the range (length of track) of an alpha particle is dependent on the speed of the particle and the material in which it is moving. Roughly measure the maximum length of the tracks. In the table in the Appendix, find the approximate energy of the alpha particles. Not all of the particles have the maximum range. This can be partly explained by the fact that not all alpha particles originate at the surface of the source. Many of them use up some of their energy in merely escaping from the source.

You will be provided with pieces of metal foil and with onion skin paper. Make small "barriers" and, using tweezers, place the barriers near the center of the chamber and replace the lid and source, as shown in Figure 7.

What do you conclude about the effects of the paper and metal barriers?

Remove the source and barriers and try to observe tracks of cosmic ray particles. This may take a little patience. These tracks will be fainter and they will occur much less often. Their lengths vary. (Cosmic ray tracks are produced by particles which are bombarding the earth from outer space.)

These observations show that the cloud chamber is a useful device. They also point to various detailed studies that can be made. Some of these are included in the following experiments.

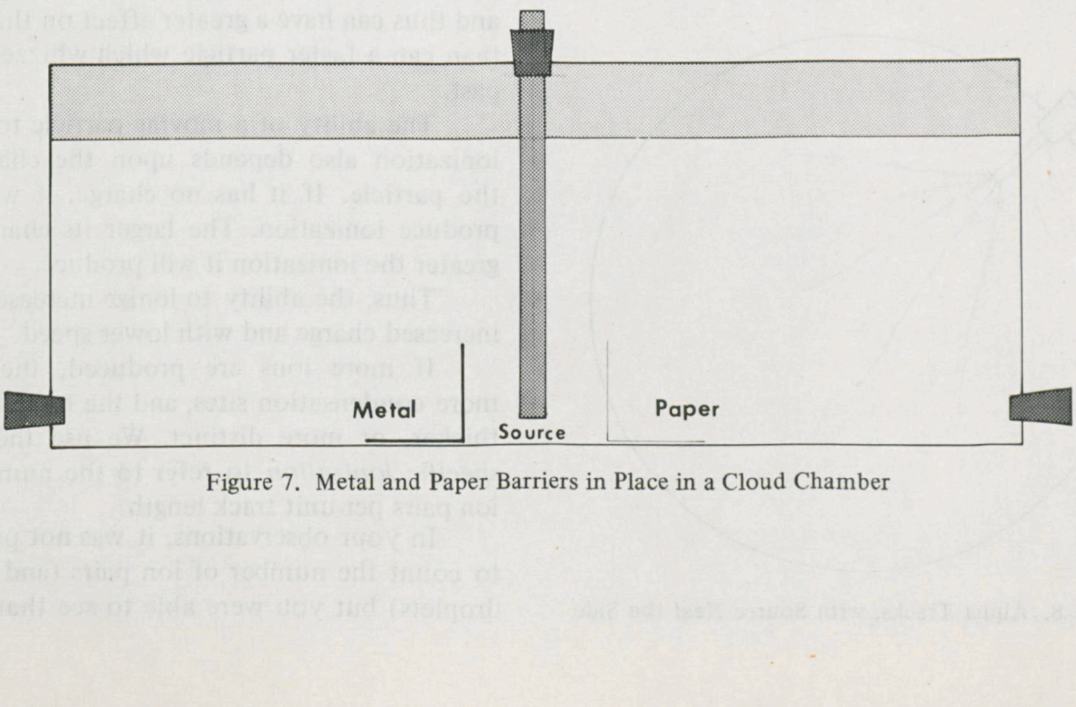


Figure 7. Metal and Paper Barriers in Place in a Cloud Chamber

Question 12.

You probably observed that alpha particles do get through onion skin paper. However, their tracks beyond the paper barrier are shorter than normal. Why?

EXPERIMENT B-2. Specific Ionization and Scattering

In this and the following experiment you will be able to study the differences between different kinds of radiation by observing some of the details of the tracks they produce in the cloud chamber. We shall observe alpha and beta radiation. Sources of these radiations are provided for your use in a few experiments. For these studies it is better to have the source inserted at the side of the chamber, and the sources are especially constructed for this purpose.

With the cloud chamber assembled and in the supercooled state, insert the polonium-210 alpha source through the side hole and observe the tracks. Note that they are heavy and straight though they may be curved somewhat near the stopping point, as indicated in Figure 8.

Now remove the alpha source and insert a beta source (thallium-204). Again observe the tracks. How do alpha and beta tracks compare? (See Figure 9.)

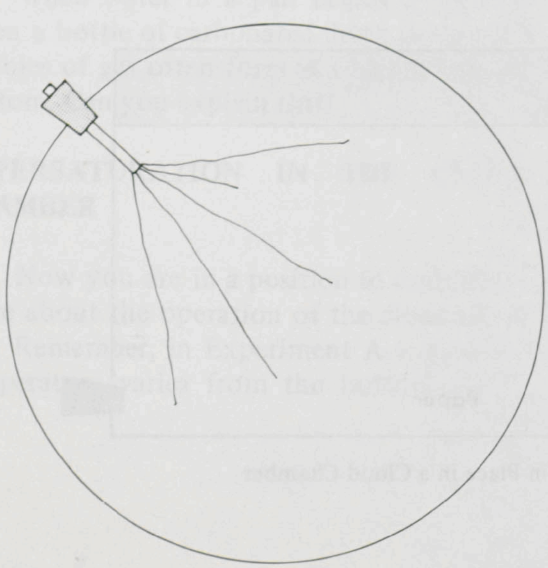


Figure 8. Alpha Tracks, with Source Near the Side

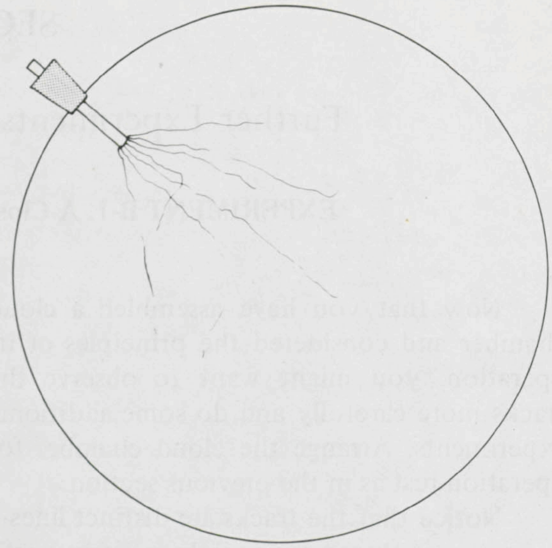


Figure 9. Tracks of Beta Particles

In order to understand the differences between alpha and beta tracks, let's take a closer look at what is happening. As mentioned earlier, charged particles moving through the gas produce many ion pairs. This is because the moving particle knocks electrons from the gas atoms. Because the electrons and the moving particles are charged particles, they can affect one another from a distance, and an actual contact collision is not necessary. The moving particle needs only to pass near an electron in an atom to knock it out and ionize the atom. But the effect produced is greater for a slowly moving particle: it stays near a particular atom longer and thus can have a greater effect on the atom than can a faster particle which whizzes right past.

The ability of a moving particle to cause ionization also depends upon the charge of the particle. If it has no charge, it will not produce ionization. The larger its charge the greater the ionization it will produce.

Thus, the ability to ionize increases with increased charge and with lower speed.

If more ions are produced, there are more condensation sites, and the track will be thicker, or more distinct. We use the term *specific ionization* to refer to the number of ion pairs per unit track length.

In your observations, it was not possible to count the number of ion pairs (and hence droplets) but you were able to see that alpha

tracks are thicker than beta tracks. This must mean that alpha particles have more charge *or* they are moving more slowly, or both. As a matter of fact, both are true. The alpha particle is about 7300 times as heavy as the beta particle and it moves much more slowly. Its charge is twice as great as that of the beta particle.

Question 13.

Can you explain why particles with larger charge produce more ions and hence heavier tracks?

EXPERIMENT B-3. Radiation Absorption

You will be provided with a few materials from which you can make small "absorbers": metal foil, a filing card, and some very thin paper. An absorber can be set on the bottom near the source, as in Figure 10.

With the chamber operating with the polonium-210 source in place, put a metal foil in front of the source. Do the alpha particles penetrate the foil? Repeat for the absorber made from a filing card and for the one made of very thin paper.

Repeat these observations with the thallium-204 source. Can you make any statements about penetrating power of the two kinds of radiation?

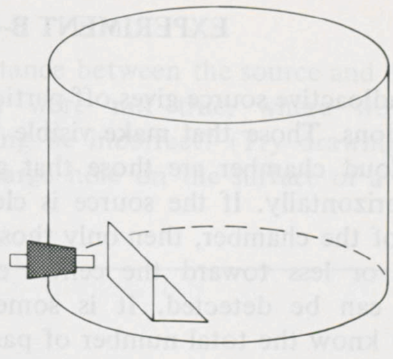


Figure 10. An Absorber in the Cloud Chamber

Question 14.

If an onion skin paper barrier becomes wet with alcohol, no alpha tracks are seen beyond it. Similarly, if the alpha source itself becomes wet, few if any tracks are seen. Why?

Question 15.

Alpha particles make heavier tracks than betas. They also have less penetrating ability than betas. How are these facts related?

EXPERIMENT B-4. Measurement of Source Activity

A radioactive source gives off particles in all directions. Those that make visible tracks in the cloud chamber are those that go off nearly horizontally. If the source is close to the side of the chamber, then only those that go more or less toward the center of the chamber can be detected. It is sometimes useful to know the total number of particles given off by a source in one second. This is called the *source activity.*

You will be provided with a metal barrier with a small circular hole. Alpha particles will not pass through the metal but *will* pass through the hole. If the absorber is placed some distance from the source, then the rate at which particles pass through the hole is small, even for a moderately strong source. By counting the small number of tracks that go through the hole, it is possible to compute the total activity of the source.

Measure the diameter of the hole (d) and assemble the source and the absorber in the cloud chamber, as in Figure 11. Measure the distance between the hole and the source (D). Observe the tracks made by alpha particles from the polonium-210 source that pass through the hole. Count the tracks that are visible in a ten-minute period. Use the letter n to represent this number.

You now have the information needed to compute the total number of particles emitted by the source in one second.

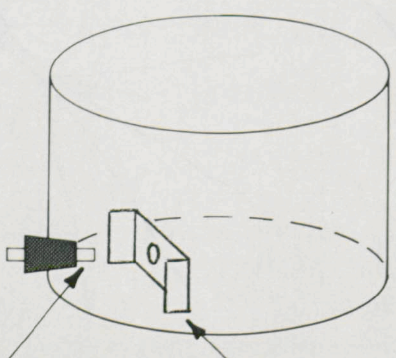


Figure 11. Cloud Chamber Arranged for Total Activity Measurement

Imagine a sphere around the source with a diameter such that the hole is at the surface of the sphere, as indicated in Figure 12. Since the source emits particles equally in all directions, the total activity, R, divided by the observed rate, n, is the same as the total area of the sphere divided by the area of the hole:

$$\frac{R}{n} = \frac{\text{area of sphere}}{\text{area of hole}}$$

Or, solving for R:

$$R = n \frac{\text{area of sphere}}{\text{area of hole}}$$

$$= n \frac{4\pi D^2}{\pi (d/2)^2}$$

This expression simplifies to:

$$R = 16\, n \frac{D^2}{d^2} = 16\, n\, (D/d)^2$$

Using your measurements, compute R in counts per minute and convert this to counts per second.

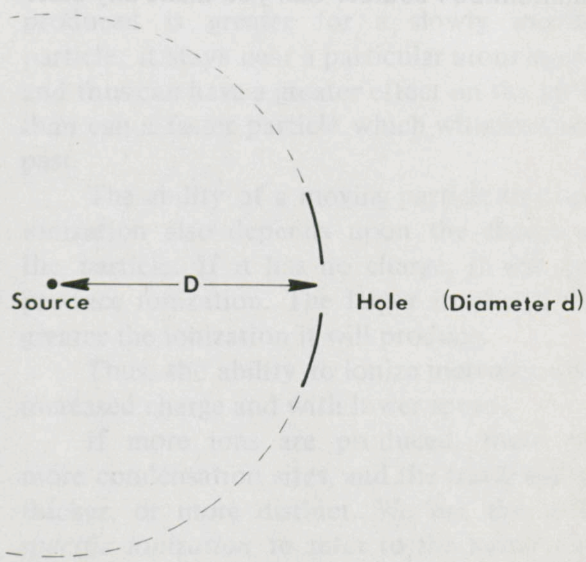


Figure 12. Diagram Used in Calculating Total Activity of a Source

Question 16.

In the derivation of the formula for total activity of a source, it is important that the diameter of the hole be small compared with the distance between the source and the hole. If this were not true, where would the reasoning be incorrect? (Try drawing a relatively large hole on the surface of a sphere.)

SUMMARY

In this section you used the cloud chamber to study the characteristics of *alpha* and *beta* radiations. You were able to compare their penetrating abilities. You also saw that alpha tracks are much heavier than beta tracks and that this is because of the larger charge and the slower speed of the alpha particles.

Finally, you took rate measurements and calculated the total number of particles given off by a source in one second.

SECTION C (Optional)

Suggestions for Further Study

EXPERIMENT C-1. Measurement of Alpha Energies

The range of an alpha particle in the cloud chamber depends on the energy of the alpha particle. To compare energies of alpha particles you will need sources which produce alphas of different energies. For each source, measure the range, using the stick probe which has been provided. Insert the probe from the side opposite the source. First, measure the length of probe sticking out of the chamber when the probe almost touches the source. Then measure the amount that sticks out when the end is located at the stopping point for the alpha particle. (See Figure 13.) The range of the particle is the difference in these two measurements. Using the information in the Appendix, plot range versus energy on a sheet of graph paper. Now, with an alpha source of unknown energy, measure the range. Using the graph, find the energy of the unknown particle.

EXPERIMENT C-2. The Effect of Magnetic Field

A moving charged particle which is in a magnetic field experiences a force which is perpendicular to its motion. In a magnetic field, a charged particle follows a smoothly curved path.

Since tracks in the cloud chamber are produced by moving charged particles, it should be possible to produce bending of the tracks by a magnetic field. The main difficulty is in getting a magnetic field that is strong enough. One way this can be done is to wrap a coil around the cloud chamber and connect it to a battery or other power supply which will produce a large electric current in the coil.

With such an arrangement, study the effect of magnetic field on both alpha and beta tracks.

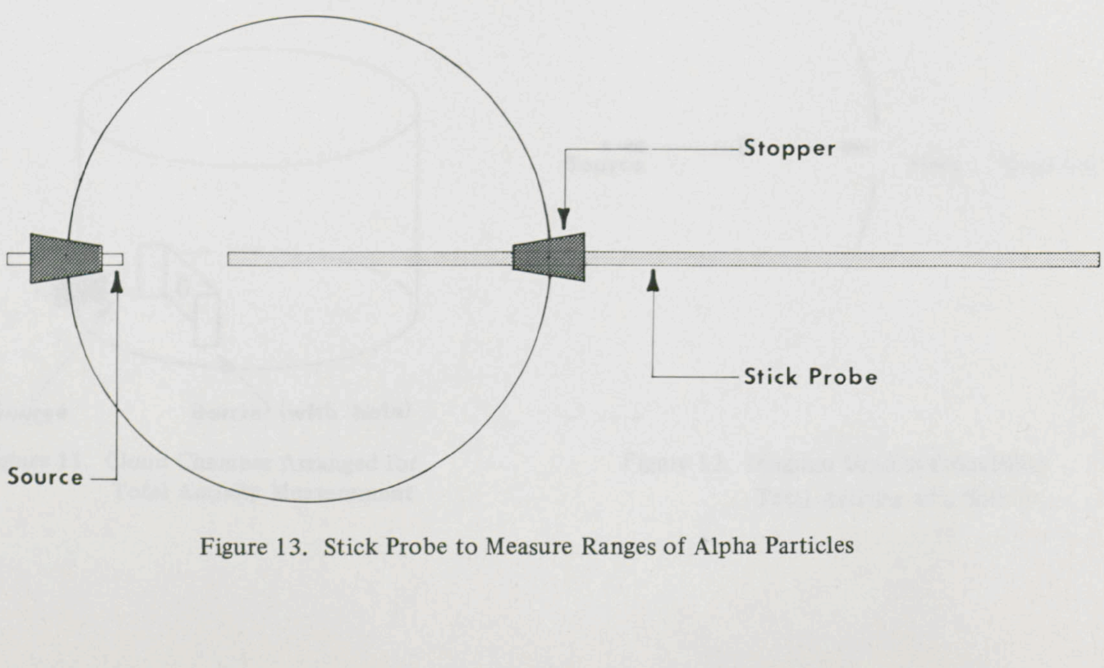


Figure 13. Stick Probe to Measure Ranges of Alpha Particles

EXPERIMENT C-3. Observing Gamma Rays

Since gamma rays are uncharged, they do not ordinarily cause tracks in a cloud chamber. They can, however, knock electrons out of a metal foil and these may have enough speed to cause tracks.

Place in the chamber a pure gamma source (for example, Barium-137) and a metal foil absorber. Can tracks be seen beyond the absorber?

APPENDIX ON ENERGY

HEAT AND KINETIC ENERGY

Of the many forms of energy, the ones that concern us in this module are *heat* and *kinetic energy*. Heat is required to change a substance from the solid to the liquid form and also from the liquid to the gaseous form. Heat is also required to raise the temperature of a substance. In each of these cases, the process can be reversed: heat is given off when the process goes backward (substance gets cooler, gas becomes a liquid, liquid becomes a solid).

Kinetic energy is the energy a body has because of its motion. It is related to the amount of material in the body (the mass m) and the speed v of the body. Expressed by a formula, it is

$$KE = \tfrac{1}{2}mv^2$$

Note that doubling the mass doubles the energy (for the same speed) but that doubling the speed gives four times the energy (for the same mass).

In the text it was pointed out that the specific ionization (which determines how thick the cloud chamber track is) is larger for low speeds. Let us see, then, if we can decide why beta tracks are thinner than alpha tracks.

The kinetic energies of alpha and beta particles from the sources used are not much different from each other. The alpha particle, however, is about 7300 times as heavy as the beta particle. Therefore it is moving much more slowly than the beta particle and hence it makes a heavier track. (The beta particle moves about 85 times faster than an alpha particle with the same kinetic energy.)

ENERGY UNITS

The unit commonly used for the energy of radioactive particles is the MeV (pronounced “em - ee - vee”). It stands for “million electron volts.” To get some idea of the size of this unit, we point out that the total energy (including heat) given off by a 100-watt light bulb in a minute is about 4×10^{16} MeV. And yet the kinetic energy of each air molecule in a classroom is a small fraction of an electron volt (*not* MeV).

ENERGY AND RANGE

The range (maximum length of track) of an alpha particle depends on the energy of the particle and the material through which it is moving. The following table gives values for the range in dry air at 15°C and standard pressure. (These are approximately correct for the cloud chamber.)

alpha energy (in MeV)	range (in cm)
1	0.5
2	1.0
3	1.7
4	2.5
5	3.5
6	4.7
7	5.9
8	7.4
9	9.0
10	10.5

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